

AD-A010 744

DEVELOPMENT OF HIGH SPEED EQUIPMENT FOR
SEALING NON-ELECTRIC DETONATORS

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MRC Corporation

Prepared for:

Picatinny Arsenal

September 1974

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NON-ELECTRIC DETONATORS

Final Report
by
Nathan D. Isaacs

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PICATINNY ARSENAL
DOVER, NEW JERSEY 07801

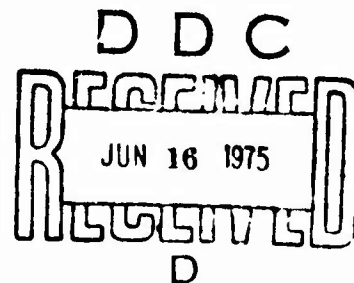
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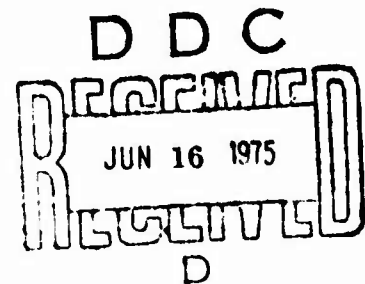
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ABSTRACT

A program was conducted to develop high speed equipment for sealing non-electric detonators at the rate of 1200 per minute. MRC conducted an engineering study of the appropriate manufacturing operations including presently employed techniques. A bench model was fabricated and inert tests were performed to evaluate the feasibility of MRC's concepts. The ability to produce a uniform product in accordance with the M55 detonator drawing requirements at the desired production rate was demonstrated. It has been concluded that it is feasible to insert closure discs and crimp and seal 1200 M55 detonators per minute using MRC's concepts.



FOREWARD

This program was performed by the MRC Corporation, Baltimore, Maryland for the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey under U.S. Army Contract No. DAAA21-74-C-0074. The Picatinny Arsenal Project Officer was Toufie Mazzawy. The principal investigator was Nathan Isaacs. This is the final report for the work completed under this contract.

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SUMMARY AND RECOMMENDATIONS

The following paragraphs briefly review the objectives of the Scope of Work for this program, MRC's concepts, bench model design, accomplishments and recommendations for future work effort.

OBJECTIVES

- Develop, design, fabricate, test and evaluate an improved method for sealing non-electric detonators.
- Combine the crimping and sealing operation into a single machine system.
- Develop a concept for a modular type of machine capable of being inserted into an automated detonator line and suitable for multi non-electric detonator use.
- Develop a concept for a machine capable of crimping and sealing 1200 detonators per minute.
- Develop concepts capable of being translated into equipment that will operate within the limits set by DOD 4145.26M, AMCR 385-100 and the National Electrical Code for Hazardous Operations.
- Design and fabricate the tooling to prove the feasibility of the selected concept to accept and position the loaded detonator, insert the closing disc and crimp and seal (with lacquer) the detonator at the desired rate while maintaining proper final dimensions and a reliable quality of seal.

The recommended procedure for performing the above objectives included an engineering study of the manufacturing operations, fabrication of a bench model and a series of inert runs to prove concept feasibility.

CONCEPT

MRC's detonator sealing concept utilizes three independent rotary turrets for inserting closing discs, crimping detonators and lacquering the crimped areas. Each turret consists of 48 independent stations which revolve at 25 RPM. The entire turret, in each instance, is dedicated to performing one of the three required operations. Loaded detonators, housed in nests with the open end up, are introduced to the closing disc insert turret via a starwheel. Closing discs are punched and inserted directly into the detonator cups which are then transferred via a starwheel to the crimp turret where successive 45° and 90° crimps are performed. A third starwheel transfers the detonators to the lacquering turret where one drop of lacquer is applied to each detonator. Following this operation the nested detonators are transferred to the packout area.

BENCH MODEL

A bench model was constructed to permit an evaluation of MRC's detonator sealing concept. Briefly stated, the bench model consists of an input turret, an output station and three single station functional turrets. Tests were performed with the individual turrets working in conjunction with the input/output devices. This was more cost effective than performing tests on a more expensive integrated system because the only dependencies between turrets are input/output functions, and MRC was able to duplicate input/output interaction on a non-integrated bench model.

ACCOMPLISHMENTS

- MRC has constructed bench model machinery capable of accepting and positioning detonators (in nests), inserting closing discs and crimping and sealing the detonators at operating conditions equivalent to those present on a 1200 per minute production machine.
- MRC has demonstrated the feasibility of its crimping and sealing concepts by performing a series of continuous inert runs on the bench model.
- MRC has demonstrated that it is possible to perform crimping and sealing operations on the M55 detonator at the rate of 1200 per minute and produce uniform, "in spec" items at this rate.
- MRC has demonstrated the ability to stamp and insert closure discs at the rate of 2400 per minute.

RECOMMENDATIONS

MRC believes that the work performed on this contract demonstrates that it is feasible to insert closure discs and crimp and seal M55 non-electric detonators at the rate of 1200 per minute. MRC therefore recommends the following:

- An extensive series of live tests on the bench model to finalize design criteria for a prototype machine. The live tests should be performed on all three turrets. However, for expediency, the Army may wish to consider only the crimp turret since, on production lines, the crimping operation has the highest frequency of incidents of the three operations studied.
- A series of water immersion and firing tests on live detonators made on the bench model to determine the adequacy of the bench model seals.
- A series of tests to define sympathetic detonation characteristics of the M55 detonator in nests to determine the minimum in line spacing of detonators on production machinery.
- An engineering design program for a prototype machine to perform disc insertion, crimping and sealing. This program should include extended live testing to assure that reliability and maintainability goals are met.

BENCH MODEL DESCRIPTION

GENERAL DESCRIPTION

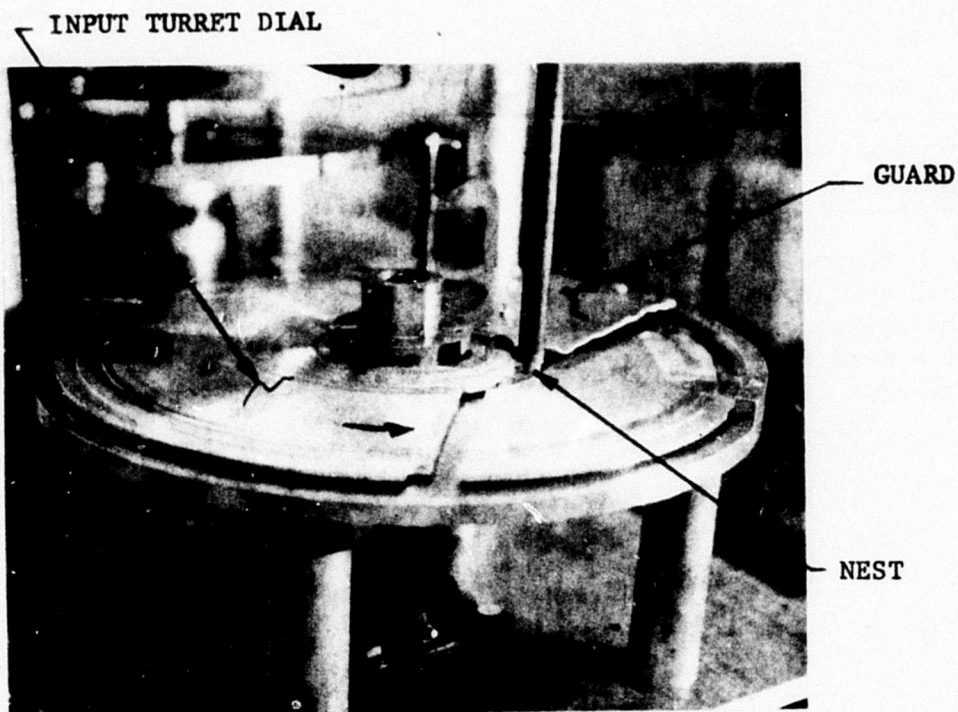
As previously discussed, MRC's detonator sealing concept utilizes three independent rotary turrets for inserting closure discs, crimping detonators and lacquering the crimped areas. Consequently it was necessary that the bench model duplicated these three operations as well as input/output functions. Because the individual turrets are independent of one another, a non-integrated bench model was fabricated.

A machine base with drive, three functional turrets, an input turret and an egress station were constructed. The input turret and egress station were assembled to the machine base and the resulting assembly was used with each of the functional turrets. Figures 1 through 15 are photographs of the bench model components. The input turret and egress station are shown working in conjunction with the closure insert turret.

In a production machine each of the functional turrets will utilize 48 stations which revolve at 25 RPM to achieve the desired production rate of 1200 parts per minute. The 48 stations would be arrayed in 24 snap-in modules (i.e. two stations per module) since the use of dual station modules is more cost effective than single station modules. For the sake of economy one module was used on each of the bench model turrets and only one of the two module stations was tooled.

INPUT TURRET: NEST FEED

Figures 1 and 2 illustrate the feeding of nests onto the input turret. The nests, containing detonators open end up, are stacked in a feed tube. The bottom nest rests on the input turret dial which has a cutout for guiding nests onto the functional turret. As the dial revolves the bottom nest drops into the cutout and is pushed against the guide rail. During the test runs a guard was added to prevent toppling of nests.



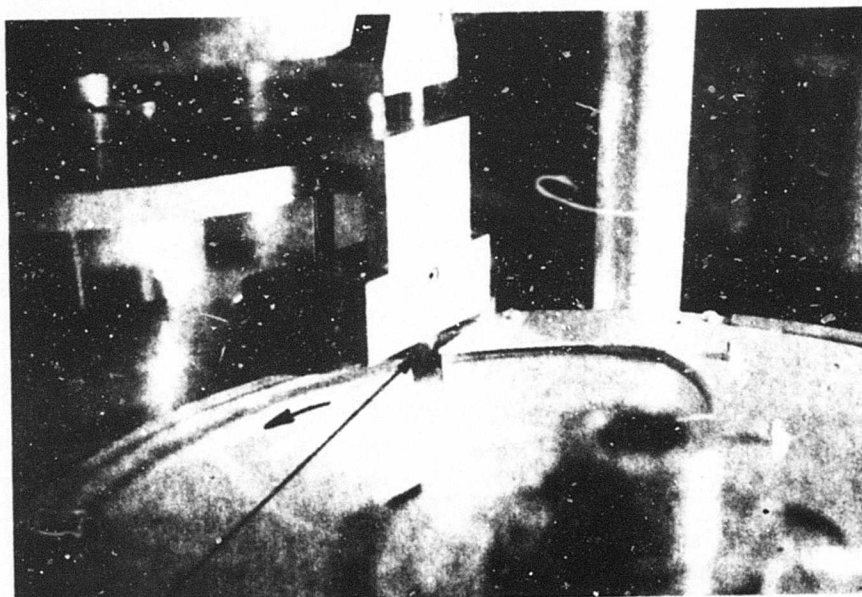
INPUT TURRET
BEFORE NEST FEED
FIGURE 1



INPUT TURRET
AFTER NEST FEED
FIGURE 2

INPUT TURRET: NEST PLACEMENT

Figure 3 shows a nest being placed onto the closure insert turret from the input turret. Both turrets are revolving at the same speed and are equal in diameter; consequently the nest is being transferred at a zero relative velocity. Figure 4 shows a side view of this transfer. The nest leaves the input turret and is placed into a spring loaded nest clip, which holds the nest while it is on the functional turret.

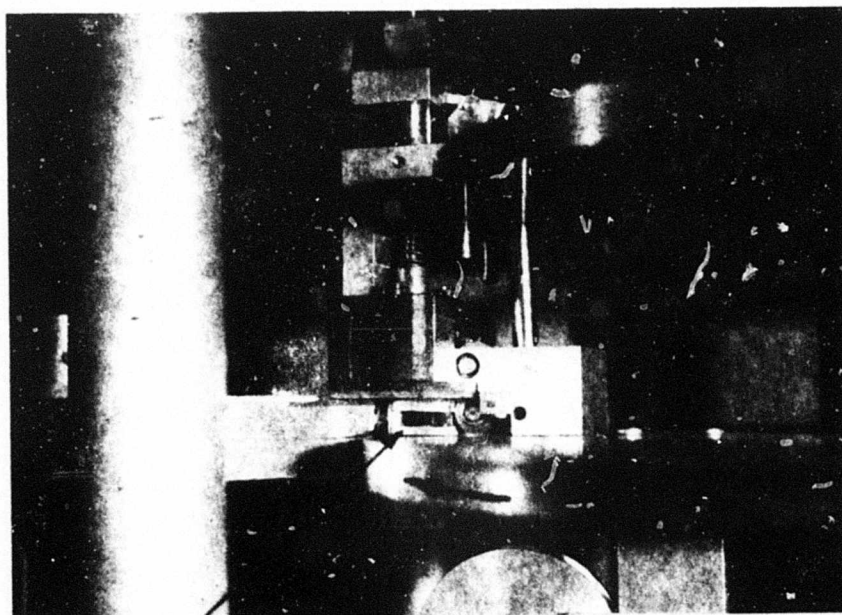


NEST —

INPUT TURRET

FRONT VIEW OF NEST PLACEMENT

FIGURE 3



NEST CLIP —

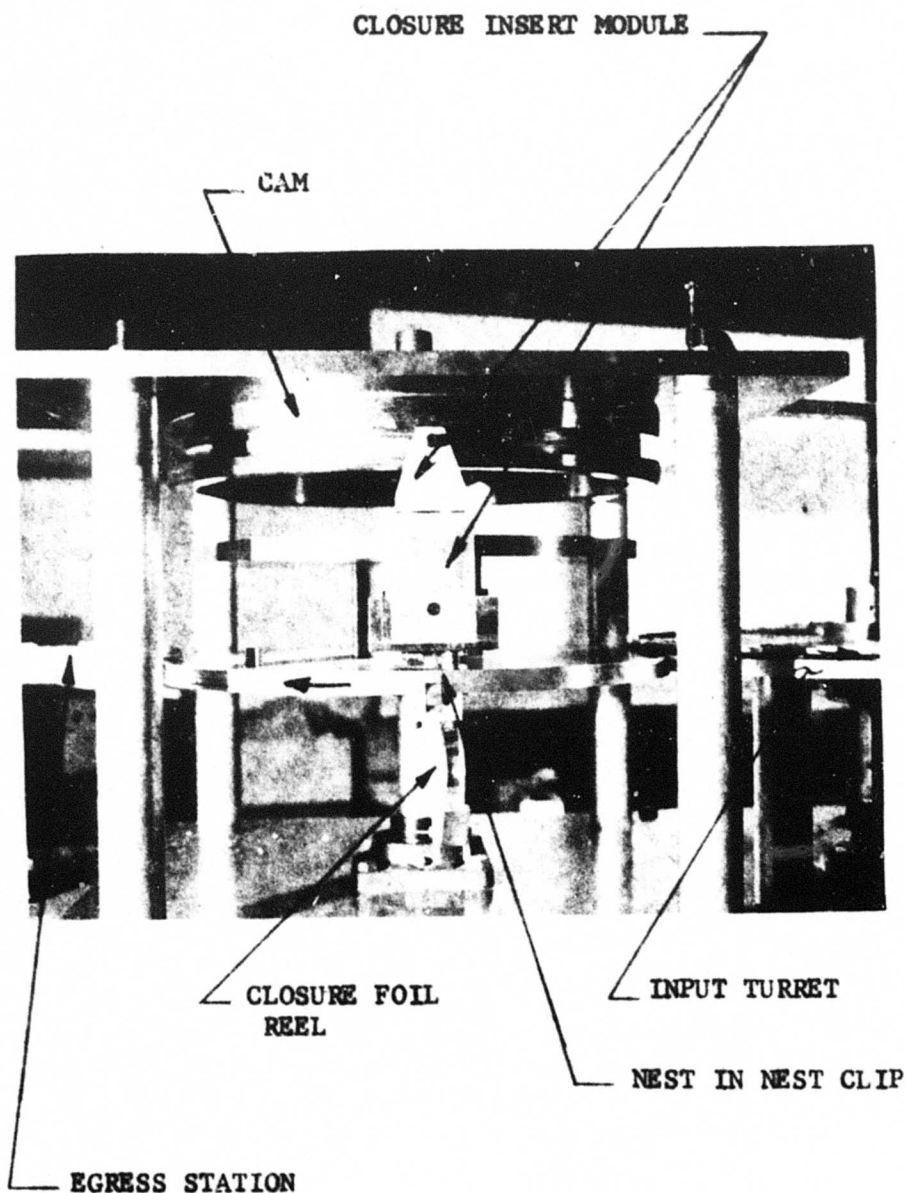
INPUT TURRET

SIDE VIEW OF NEST PLACEMENT

FIGURE 4

CLOSURE INSERT TURRET

Figure 5 shows a frontal view of the closure insert turret during the blanking operation. As can be seen on the photograph, the closure insert module has fixed and floating components. The blanking punch and die, foil supply and foil advance mechanism are part of the fixed portion. The floating (upper) section is guided by a circular cam. During nest ingress the floating section is up; however, it is forced down by the cam as the dial revolves. Blanking is performed 90° relative to nest ingress. As the dial continues its rotation, the floater raises--causing the foil to advance--reaching the full up position at nest egress which is performed 180° relative to ingress. A foil takeup was not used on the bench model. Instead an on-the-fly cutter was used at the 270° position.

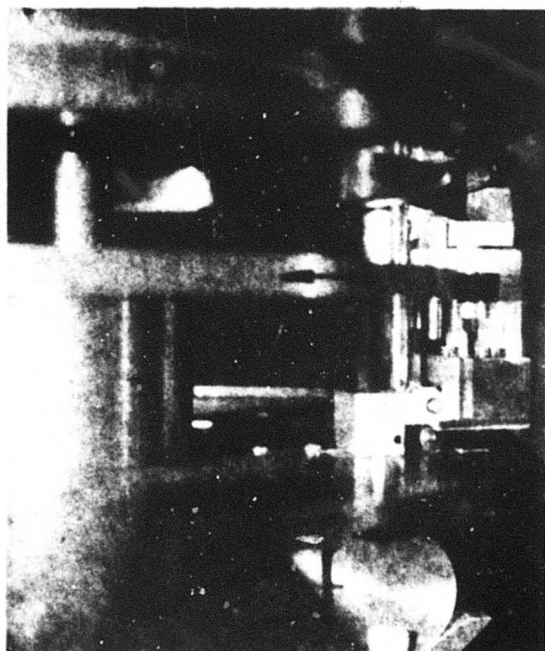


CLOSURE INSERT TURRET
FRONTAL VIEW OF BLANKING OPERATION
FIGURE 5

CLOSURE INSERT TURRET: FOIL ADVANCE

Figure 6 shows the closure insert module during the closure disc blanking operation. The floating actuator has been forced down by the upper cam track. The punch, which is positioned directly below the actuator, has in turn been forced down causing a closure disc to be blanked and inserted into a detonator cup.

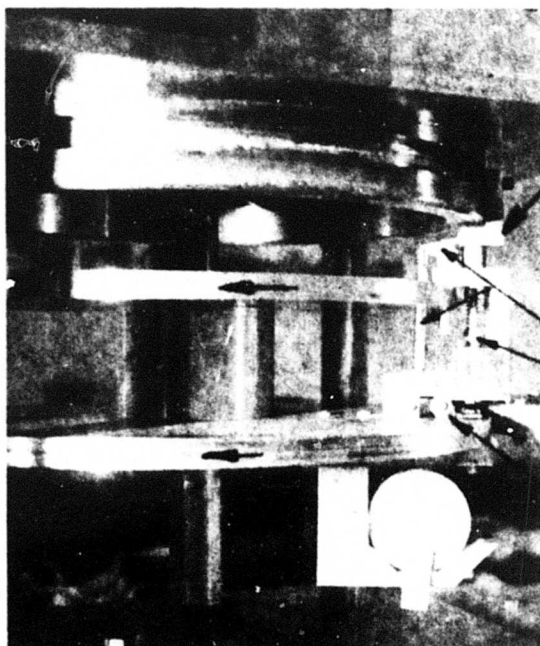
Figure 7 illustrates the position of the insert module at the nest egress station. The actuator is now in the up position. During the elevation step the closure foil has advanced. Foil advance is accomplished when the actuator lifts the foil advance lever, which in turn depresses the advance bar causing the drive roller to turn. Tension is maintained on the foil by a spring loaded idler roller below the foil. A one way clutch is used to link the foil advance drive roller to the advance bar. This prevents the foil from reversing during the actuator down stroke.



ACTUATOR DOWN
DURING BLANKING

DIE

CLOSURE INSERT TURRET
SIDE VIEW DURING BLANKING OPERATION
FIGURE 6



ACTUATOR UP DURING NEST
EGRESS/INGRESS

FOIL ADVANCE BAR/LEVER

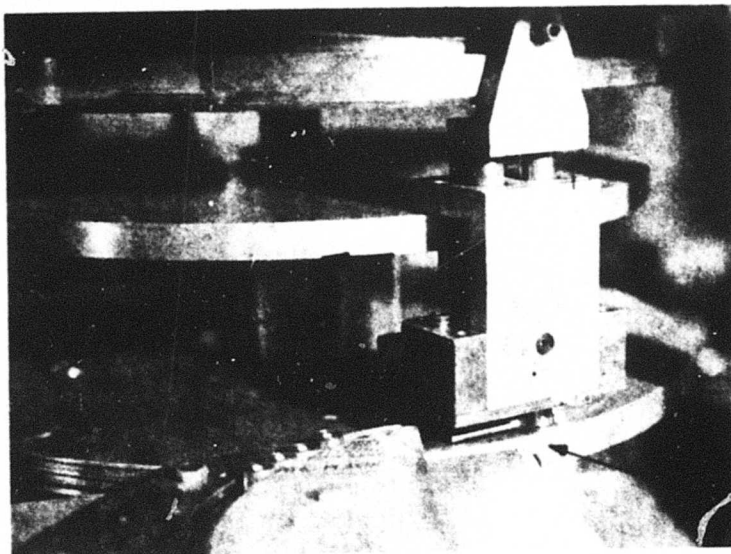
PUNCH

FOIL ADVANCE ROLLER
AND CLUTCH

CLOSURE INSERT TURRET
SIDE VIEW AFTER FOIL ADVANCE
FIGURE 7

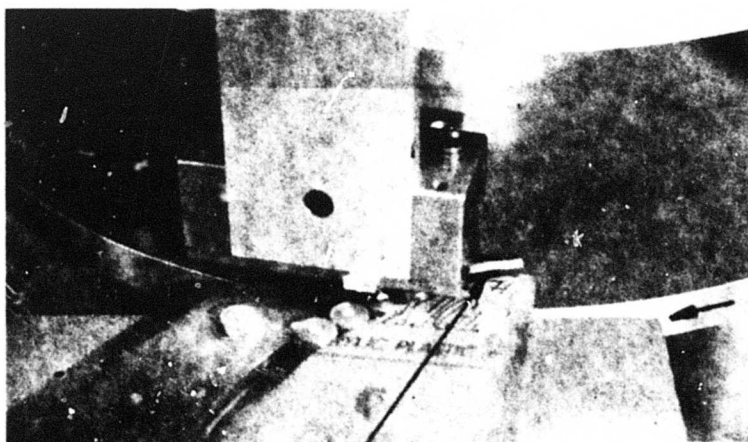
EGRESS STATION

Figures 8 and 9 show the egress (or exit) station working in conjunction with the closure insert turret. As the insert module approaches the egress station the fixed egress plough meshes into the nest clip behind the nest forcing the nest out of the clip and onto the egress station support plate.



NEST

EXIT STATION
BEFORE NEST EGRESS
FIGURE 8

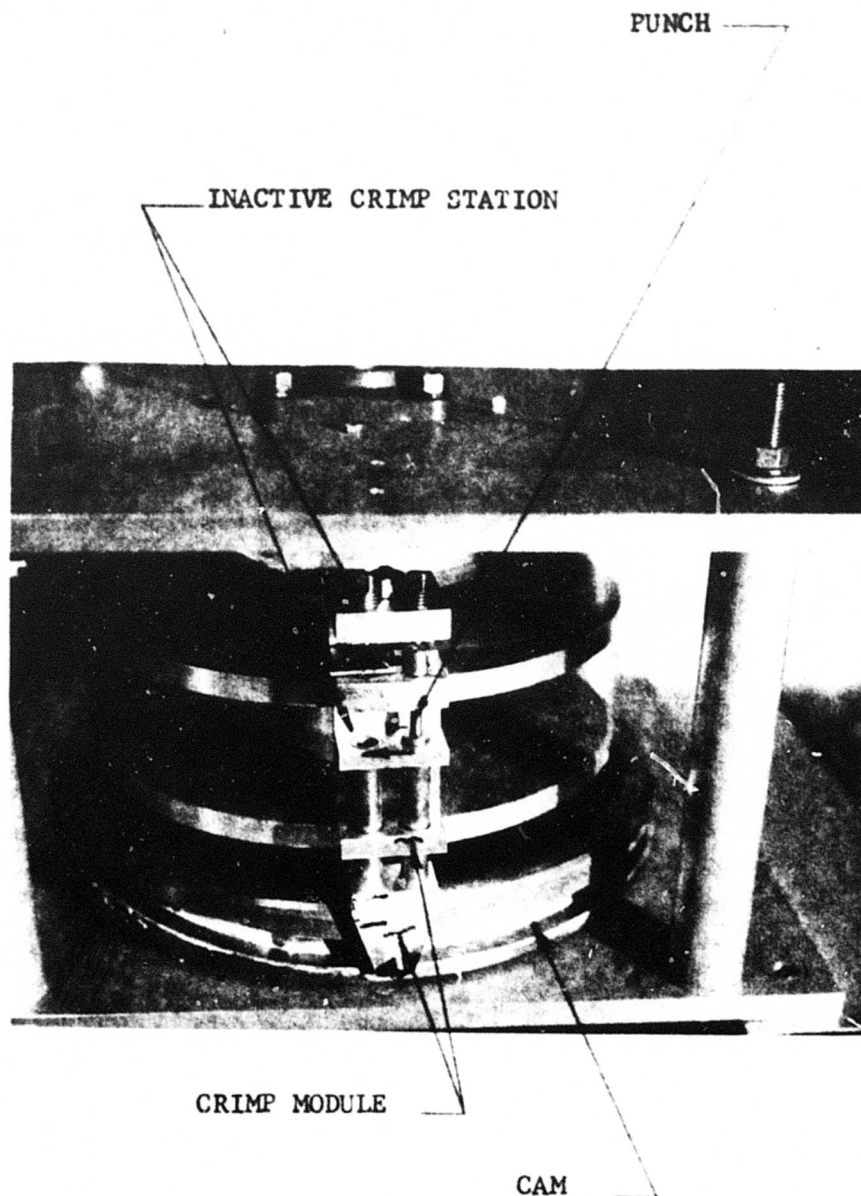


EGRESS PLOUGH

EXIT STATION
AFTER NEST EGRESS
FIGURE 9

CRIMP TURRET; PRIOR TO FIRST CRIMP

Figure 10 is a photograph of the crimp turret prior to the first crimp. Like the insert module, the crimp module has fixed and floating portions. However in this instance the actuator is driven by a cam at the base of the turret and there is a fixed linkage between the punch and actuator. The operation of MRC's crimp module differs from common load line techniques in that the detonator to be crimped is advanced to fixed crimping dies whereas conventional equipment utilizes moving crimp punches which advance to a fixed detonator. Prior to performing the first crimp the nest is in place in a nest clip and the actuator and punch are down.



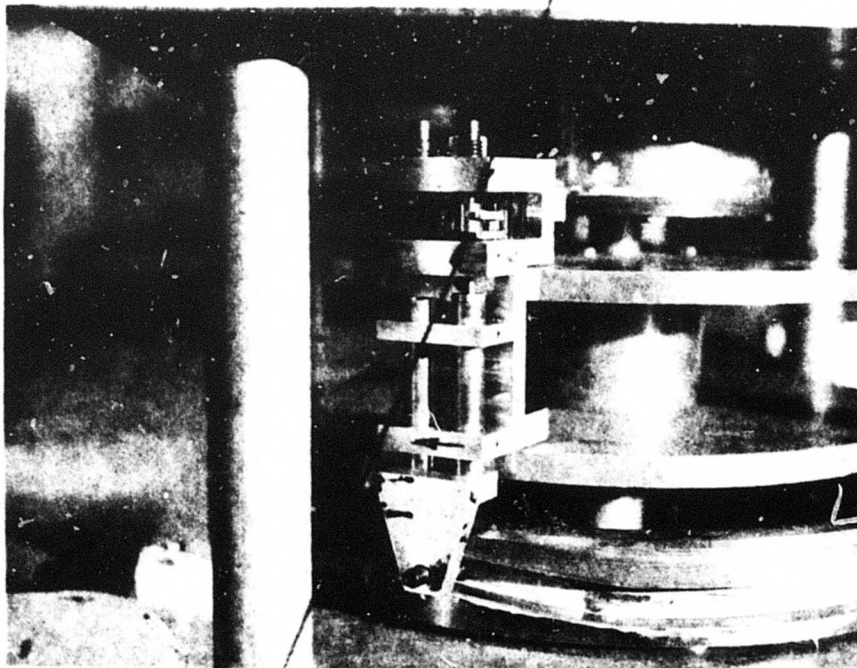
CRIMP TURRET
PRIOR TO FIRST (45°) CRIMP
FIGURE 10

CRIMP TURRET: DURING FIRST CRIMP

Figure 11 shows the crimp turret during the first crimp. The sequence of operation is as follows:

- The actuator portion of the crimp module begins its ascent.
- The punch enters the nest and begins lifting the detonator cup until a step on the punch contacts the bottom of the nest.
- As the punch continues its upward movement, the nest is lifted and the protruding detonator enters the 45° crimp die.
- When the top of the nest bottoms against the crimp die, a spring in the punch compresses relieving potential overpressure conditions.
- The actuator begins its descent.

45° CRIMP DIE



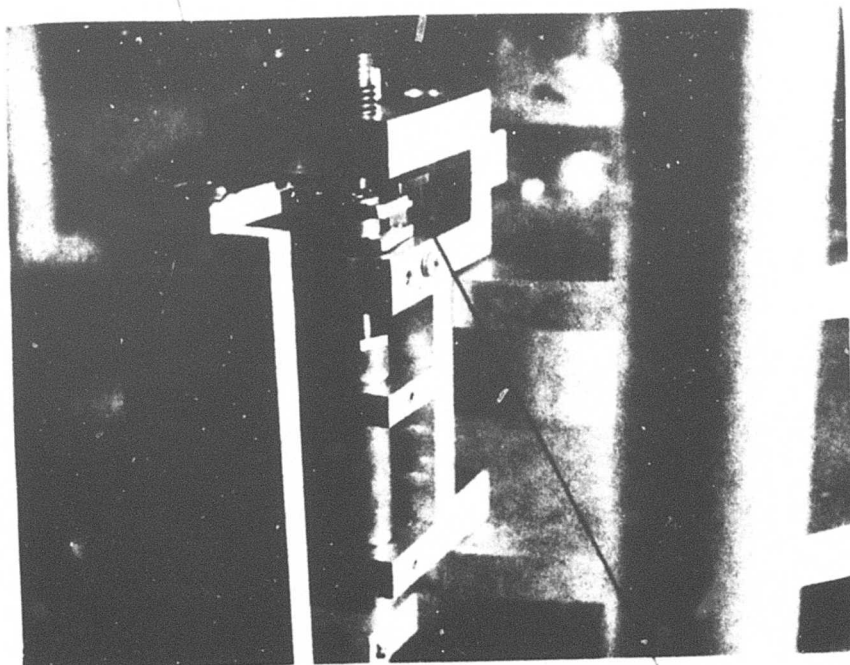
NEST SUPPORTED BY PUNCH
DURING CRIMPING OPERATION

CRIMP TURRET
DURING FIRST (45°) CRIMP
FIGURE 11

CRIMP TURRET: AFTER FIRST CRIMP

Figure 12 shows the crimp module following the 45° crimp. Careful examination reveals that the detonator cup is protruding above the nest and that the nest is elevated off the module base. The nest remains elevated because the pressure of the nest clip prevents free descent of the nest. Consequently an auxiliary cam has been added to the turret to complete the descent of the nest below the plane occupied by the flat crimp reaction plate.

AUXILIARY CAM TO LOWER
NEST AFTER 1ST CRIMP

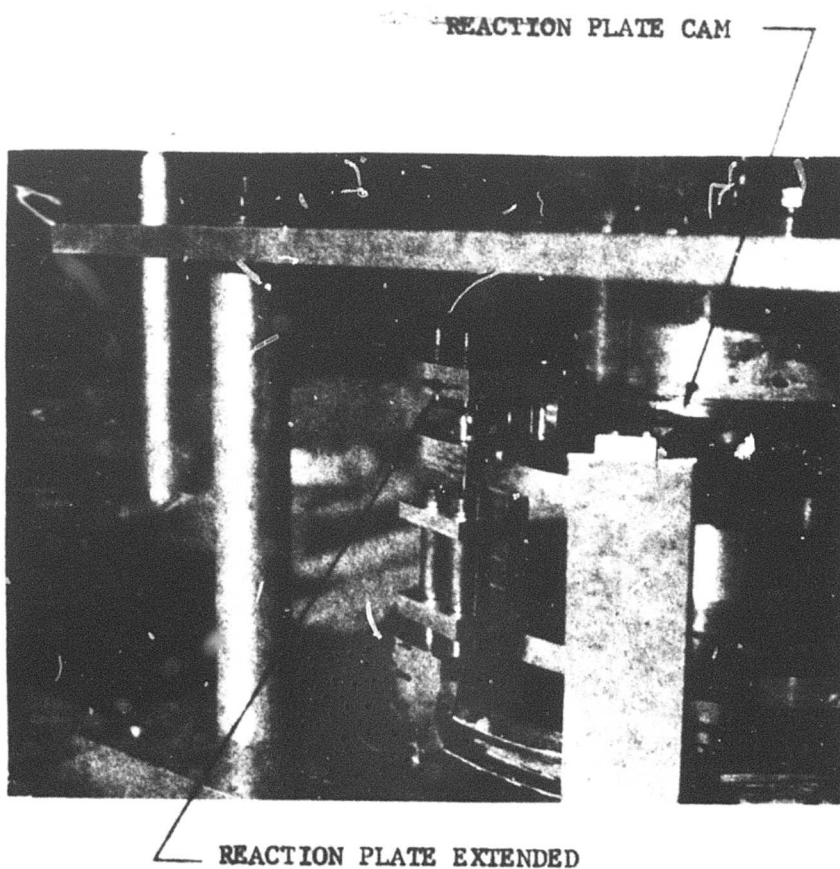


FLAT CRIMP REACTION
PLATE RETRACTED

CRIMP TURRET
AFTER FIRST (45°) CRIMP
FIGURE 12

CRIMP TURRET: PRIOR TO FLAT CRIMP

Figure 13 shows the crimp turret prior to the flat crimp operation. The actuator is down and the nest is resting on the module base. A plate which reacts the flat crimp has been positioned below the 45° crimp die and above the nest. This plate is motivated forward by an eccentric cam located around the turret center shaft. The reaction plate is spring loaded to permit retraction after the flat crimp operation.



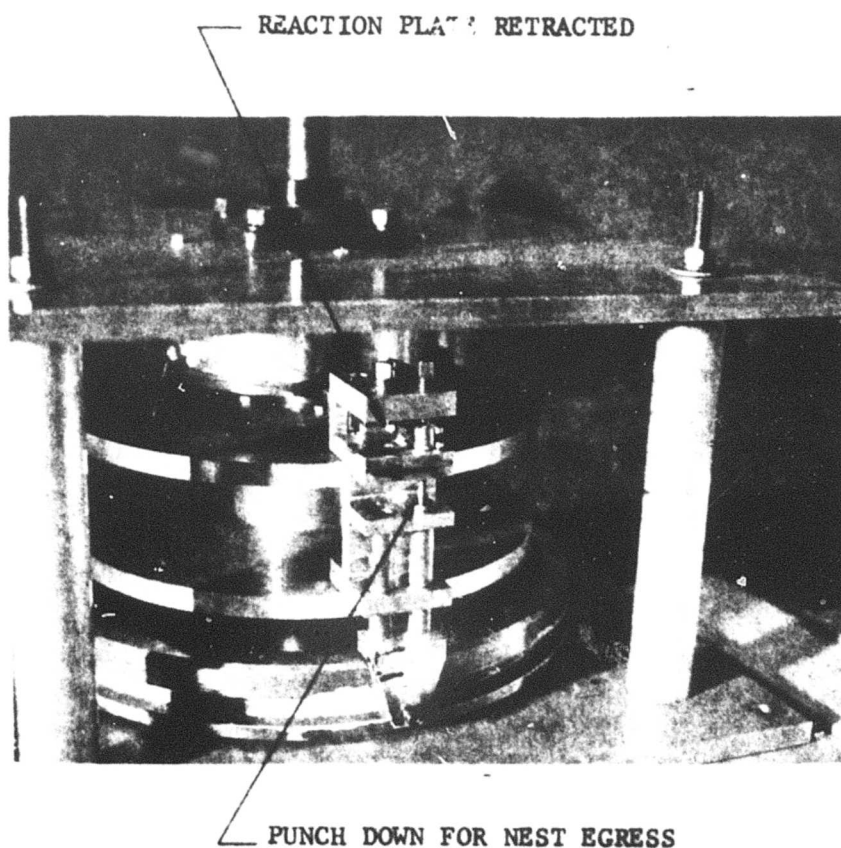
CRIMP TURRET
PRIOR TO FLAT CRIMP
FIGURE 13

CRIMP TURRET: AFTER 45° AND FLAT CRIMPS

The operation sequence for the flat crimp is as follows:

- The flat crimp reaction plate extends
- The actuator and punch ascend supporting both the detonator and the nest and driving them against the reaction plate. The 45° die prevents upward deflection of the reaction plate.
- The punch spring compresses as the actuator continues its ascension.
- The actuator descends and the reaction plate retracts.

Figure 14 shows the crimp turret following the flat crimp.



CRIMP TURRET
45° AND FLAT CRIMPS COMPLETED
FIGURE 14

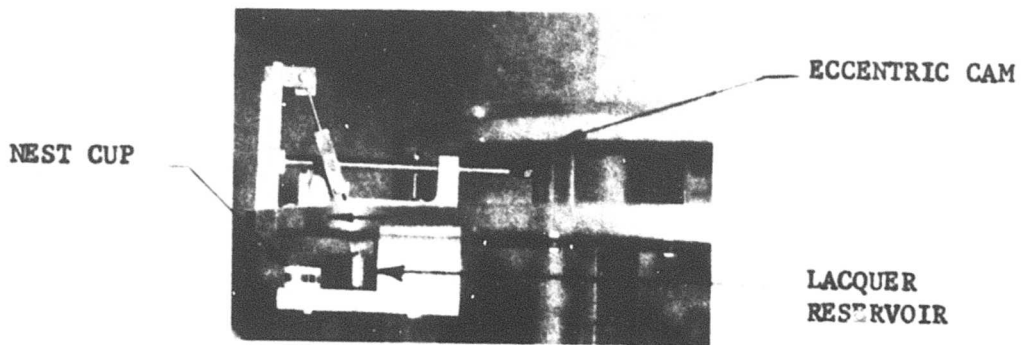
LACQUER TURRET

Figure 15 illustrates the operation of the lacquer turret. A steel punch or quill is used to deposit a single drop of lacquer on the crimped detonators. This is essentially the same technique that is used on existing packout lines.

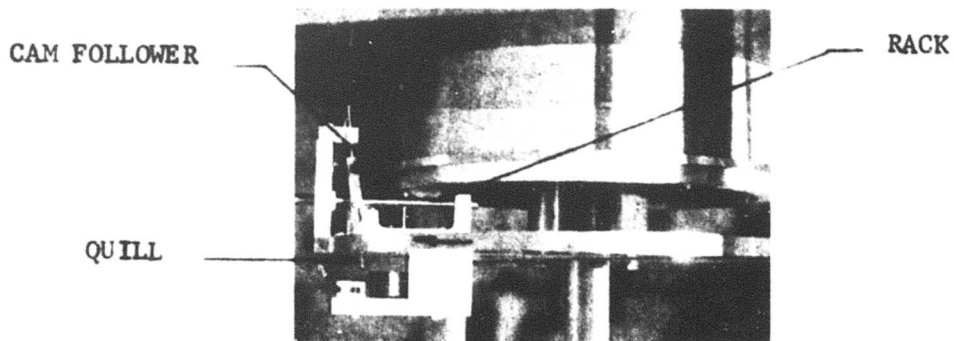
View 1 shows the quill in the reservoir. The movement of the quill is controlled by a rack and pinion which is driven by a cam follower working within an eccentric cam around the turret drive shaft.

View 2 shows the quill midway between the nest and reservoir. The quill holder is linked to a pinion so that it lifts as the pinion turns in the rack. The holder is slotted to prevent the quill from being driven into the crimped detonator surface as the linkage point descends.

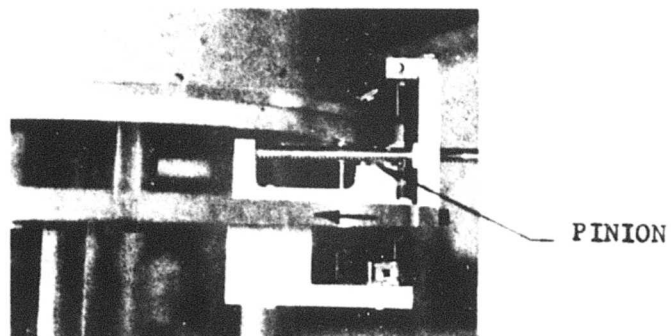
View 3 shows the position of the quill as it contacts the detonator.



VIEW 1. QUILL IN RESERVOIR



VIEW 2. QUILL ADVANCING TOWARD NEST



VIEW 3. QUILL DEPOSITING LACQUER

LACQUER TURRET

FIGURE 15

RESULTS OF DEMONSTRATION RUNS

Demonstration runs were performed on the three functional turrets to determine whether MRC's bench model design could be projected into a production prototype system. The first demonstration run for the closure insert turret was unsuccessful. However a subsequent closure insert turret run and the crimp turret and lacquer turret runs were successful and it was concluded that the tests demonstrated that the bench model design could be projected into a production prototype system.

CLOSURE INSERT TURRET DEMONSTRATION RUNS

The results of the demonstration tests for the closure insert turret are tabulated in Table 1 and Table 2. The first series of runs with this turret were unsatisfactory. There were three significant problem areas.

- Input turret jams occurred.
- The frequency of "no disc" rejects was too high.
- Several foil advance mechanism jams occurred.

Following the runs an analysis of failure modes was made and corrective redesign was performed.

It was determined that the jams in the input turret were caused by the tendency of nests to fall over. Sheet metal guards were added to the turret to prevent nests from toppling. This remedied the situation.

The other two problems were more troublesome. The cause for these maladies were a result of punch and die wear. MRC's original design incorporated a fixed link between the blanking punch and the cam driven module actuator. Consequently any side loading on the actuator was directly transmitted to the blanking punch causing wear. It should be noted that the third closure foil necessitates a size-to-size punch and die. As wear occurred burrs formed on the discs causing them to hang on the punch causing the no disc rejects. Furthermore these burrs accumulated in the die and eventually the punch seized preventing foil advance.

The punch and die on the insert module were reworked. The link was removed between the punch and actuator. A spring was added to the punch to permit it to raise when the actuator raised. A spring loaded stripper was built into the punch to prevent discs from sticking to the punch. After making these design changes a second demonstration run was performed. This second series of tests were successful. Runs were performed at 25,36 and 50 RPM.

<u>TEST NUMBER</u>	<u>DETONATORS PROCESSED</u>	<u>REJECTS (NO DISCS)</u>	<u>REMARKS</u>
1	102	1	
2	48	3	
3	82	3	Input turret jam
4	30	2	" " "
5	41	5	" " "
6	64	2	Foil advance mechanism failure
7	115	0	" " " "

DEMO 1. CLOSURE INSERT TURRET @ 25 RPM

TABLE 1

<u>TEST NUMBER</u>	<u>SPEED (RPM)</u>	<u>DETONATORS PROCESSED</u>	<u>REJECTS (NO DISCS)</u>	<u>REMARKS</u>
1	25	616	2	Foil advance jam (15 min. repair time)
2	25	645	2	
3	36	215	0	Foil advance jam
4	50	168	0	" " "

DEMO 2. CLOSURE INSERT TURRET

TABLE 2

CRIMP TURRET DEMONSTRATION

Table 3 lists the results of the crimp turret demonstration runs. Sustained runs of more than 204 detonators were not possible because the number of nests available was limited. A crimp with a deformed closure disc was considered a reject. Detonators that had overall height in excess of the drawing requirements were not considered as rejects since the height dimension was directly affected by charge height variations on the Government furnished inert detonators.

<u>TEST NUMBER</u>	<u>SPEED (RPM)</u>	<u>DETONATORS PROCESSED</u>	<u>CHARGE HEIGHT (INCHES)</u>	<u>REJECTS (DEFORMED DISCS)</u>	<u>DETONATORS ABOVE OVERALL - HLIGHT REQUIREMENT</u>
1	20	190	.129 to .132	4	13
2	22	191	.130 to .131	2	16
3	25	190	.134 & Above	5	All
4	25	190	.129 to .135	9	14
5	25	204	.129 to .135	6	17
6	25	204	.129 to .135	3	15
7	25	30	.129 to .135	1	0

DEMO 3. CRIMP TURRET

TABLE 3

LACQUER TURRET DEMONSTRATIONS

Table 4 contains the results of the lacquer turret demonstration runs. As in the case of the crimp turret tests, sustained runs were not possible due to the limited number of nests available. All tests were run at 25 RPM. A lacquer mixture of 20 parts lacquer to 50 parts thinner was used. The quill tip was reduced from .093 inch on test one to .076 on tests 2 through 6 to eliminate excessive lacquer buildup on nests.

<u>TEST NUMBER</u>	<u>DETONATORS PROCESSED</u>	<u>REJECTS (PARTIAL COVERAGE OF CRIMP INTERFACE)</u>	<u>REMARKS</u>
1	30	0	Quill tip .093 inch
2	230	2	Quill tip .076 inch
3	230	2	Rejects occurred on first two detonators
4	230	2	
5	230	10	7 Rejects were due to Quill misalignment after a input turret jam. Reset time was 3.2 minutes.
6	50	0	
7	180	All	Evaluated .075 inch diameter ball shaped quill

DEMO 4. LACQUER TURRET

TABLE 4

FUTURE DESIGN CONSIDERATIONS

Because of limited time and funding MRC was not able to investigate many designs which were applicable to high speed sealing of detonators. In addition there were instances where the demonstration runs indicated possible areas of improvement which should be implemented, or at least considered, before prototype machinery is built. A list of future design considerations is included below.

CLOSURE INSERT TURRET

- A cutoff device was used on the bench model in place of a foil takeup reel. Because of the thin cross section of the foil, a takeup reel should be considered.
- Foil was pushed into the blanking die on the bench model. A more effective approach would be to pull the foil through. If this is not feasible, the patterned drive roller should be replaced with a plain rubber roller.

CRIMP TURRET

- The 45° crimp die should be equipped with a suction port so that detonators can be scavenged between the 45° and 90° crimp steps.
- The possibility of performing the 45° crimp and 90° crimp on separate turrets should be considered.

LACQUER TURRET

- Work should be performed to determine the optimal quill tip design.
- The configuration of the lacquer reservoirs should be such that evaporation of thinner is minimal.
- The use of a turret for cleaning lacquer (and explosives) from nests should be considered.

The process operations studied on this contract comprise only a few of the necessary steps in the production of M55 non-electric detonators. Consequently the crimping and sealing equipment developed by MRC must eventually be integrated with loading and packout machinery. To accomplish such an integration, a concept for transferring detonators between machines must be developed, and criteria regarding machine interfaces must be established.

One basis for the work performed on this and a similar MRC contract, which dealt with high speed loading of M55 detonators, has been that the detonators would be handled in nests during processing. MRC believes that this is the safest and most cost effective method of handling the M55. Another approach, which is being considered by the Army, is the use of chain with built in "nest links" for movement of detonators. MRC considers the use of chain to be a marginally feasible albeit costly and highly impractical concept. In addition the use of chain will necessitate numerous modifications in the design of the crimping and sealing turrets. It is therefore recommended that a decision regarding the use of nests versus chain be made at the earliest possible opportunity.